Synopsis

Magnesium alloys have emerged as a promising material for light-weighting due to their potential for higher weight saving compared with advanced high-strength steel, aluminium alloys and glass fibre reinforced polymer composites based on equal stiffness or strength. Even though magnesium alloys offer low density, high strength to weight ratio and excellent machinability their poor creep resistance and low yield strength at elevated temperatures (~150oC) restricts their use in automotive powertrain applications. Possible ways of improving the creep resistance include development of creep resistant alloys and/or reinforcing the alloy with ceramic particulates, fibres/whiskers.

Several magnesium alloys such as – Mg-Zr based alloys, Mg-Al-RE alloys (RE: rare earth), Mg-Al-Ca alloys, Mg-Al-Sr alloys, Mg-Al-Sr-Ca alloys, Mg-Al-Si alloys offer improvement in creep resistance to different extent. However, these alloys are relatively expensive than the widely used Mg-Al-Zn alloys. Some of these alloys are unsuitable for die casting application due to cracking or die filling problems for example, in Ca and Sr containing alloys their content must be controlled to avoid castability problems.

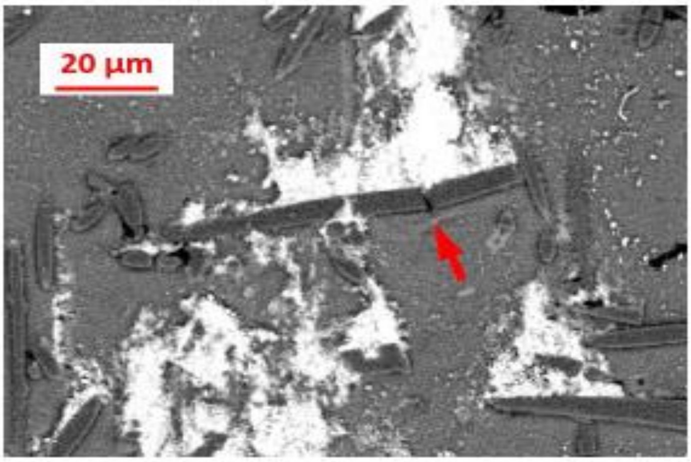
Discontinuous reinforcement of magnesium alloys opens up wide variety of casting techniques for production. Most of the components do not require high performance capability all throughout the component. Squeeze casting technique can be used to economically produce selectively reinforced composites having complex near-net-shape components. By selectively reinforcing only the regions of stress concentration, material property can be optimised at the same time lowering both the cost of manufacturing and machining.

In the present study, wear behaviour of Saffil short fibre reinforced AZ91D Mg alloy composite prepared by squeeze casting is explored. The Mg-Saffil composite had a two dimensional planar random fibre orientation which was inherent to the fabrication process of porous fibre preform. In the as-polished specimen fibres protrude out of the Mg matrix due to differential polishing. The Mg-Saffil composites were subject to unidirectional sliding wear against steel counterface under nominally dry condition in ambient atmosphere at low velocities, to simulate the piston reversal at the top dead centre of an engine wherein lubrication starvation results in wear of engine cylinder. The fibres protruding out of the magnesium matrix prevent the softer Mg matrix coming in contact with the counterface material. The worn surface was examined by means of scanning electron microscopy and the physical and chemical changes caused by the wear processes were characterised using different spectroscopic techniques.

The effect of fibre distribution and fibre orientation on wear of the composite was studied. Depending on the radius of curvature of the counterface, inhomogeneities in the fibre distribution up to a certain length scale were permissible without deteriorating the wear resistance of the composite. The normal fibre orientation proved deleterious to the wear of the counterface. But wear of the composite was independent of the fibre orientation of the wear surface.

In contrast to unreinforced AZ91 Mg alloy which undergoes extensive wear, the steel counterface was machined by the hard alumina fibres protruding out of the matrix. With progressive sliding a discontinuous patch of transferred material formed on the worn surface. Eventually, an oxidised

iron-rich transfer layer formed on the worn surface due to compaction of the transferred material and wear debris under the combined action of applied normal load and frictional force. The coefficient of friction plateaus following an initial rapid increase with the increase in the areal coverage of the transfer layer. The abrupt increase in friction coincides with the change in contact at the sliding interface from protruding alumina fibres/steel counterface to mostly between the transferred layer and steel counterface. The increase in friction due to the iron-rich transfer layer



Increase in friction due to the transfer layer leads to fibre fracture.

formed on the worn surface induced bending stresses in the fibre.

A correlation between the incipient fibre fracture and build-up of the transfer layer was observed. Wear of the composite was governed by the dawn of the fibre fracture event, which in turn leads to three-body wear.

Diamond-like carbon coatings are well-known for their low friction, high hardness and elastic modulus, chemical inertness and optical transparency. They have found widespread use due to their superior tribological characteristics as protective coatings for magnetic storage media (hard-disk drives), in micro-electromechanical devices (MEMS), biomedical applications (joint implants, artificial heart valves), optical windows (anti-reflection coating) and razor blades. The physical and mechanical properties of these coatings can be tailored by controlling the sp3 /sp2 ratio and modification via alloying with metals such as W, Ti, Cr, Al; or non-metallic elements such as B, N, F, Si.

A tungsten doped hydrogenated diamond-like carbon coated steel counterface was used to rule out or minimise any chemical and physical interaction between the composite and the counterface. The composite exhibited a higher wear resistance when slid against a DLC coated steel counterface due to ease of interfacial sliding between the carbon-rich transfer layer and the DLC coated counterface. The transition from ultra-mild to mild wear was not altogether suppressed but delayed to higher loads, prolonging the ultra-mild wear regime. As a result of reduced friction the point of maximum shear stress recedes from the surface, which manifests as subsurface cracks. The dominant wear mechanism of Mg-Saffil composite sliding against the DLC coated counterface was delamination wear.